Journal of the INTERNATIONAL SOCIETY for PLASTINATION

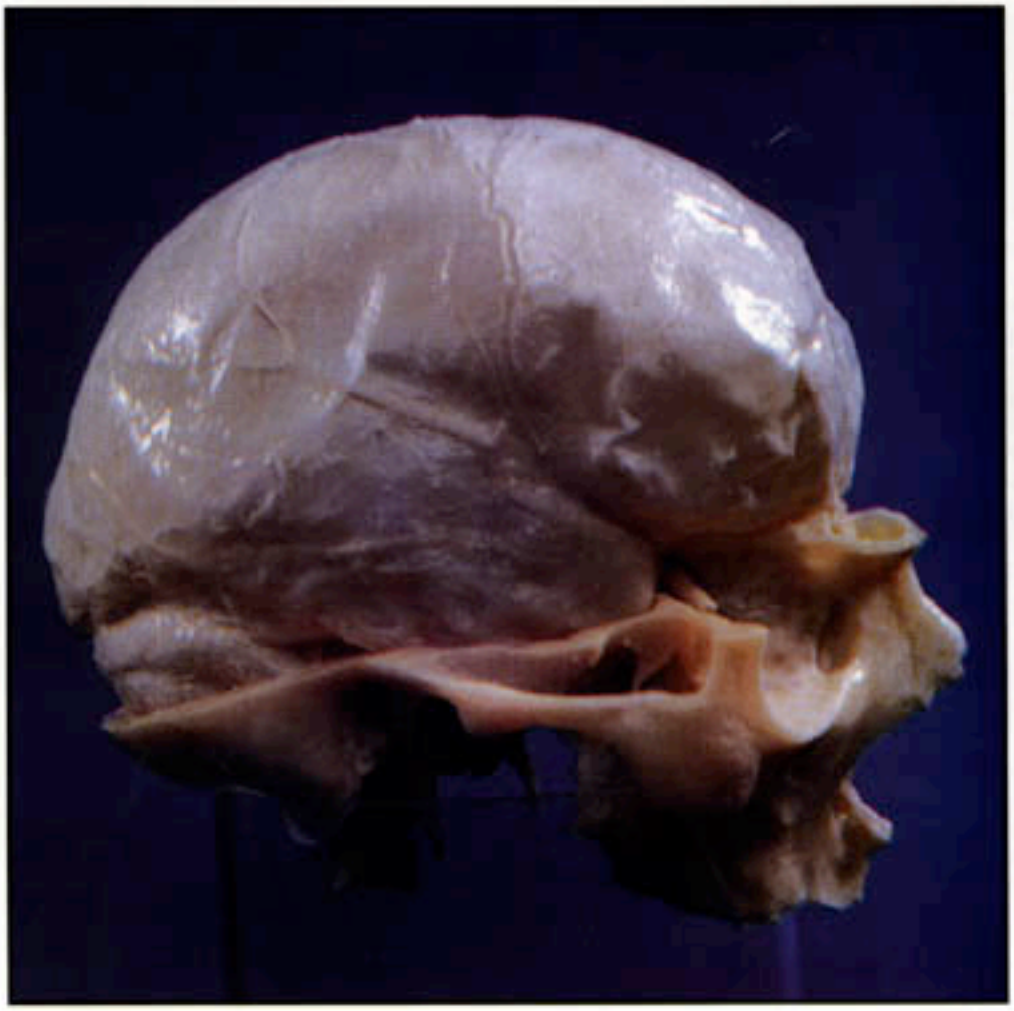

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TABLE OF CONTENTS

Message from the President....3

EDITORIAL

From scientific popularization to voyeurism: what about exhibition of plastinated specimens?....4
Régis Olry

ARTICLES

Mannheim Journal: Anatomy on Display, and It's All Too Human....5
Edmund L. Andrews

Short History of Vascular Injections, with Special Reference to the Heart Vessels....7
Régis Olry

Plastination of Three Dimensional Brachial Plexus with P40....12
Mircea-Constantin Sora

Plastination of Sturgeons with the S10 Technique in Iran: the First Trials....15
M.H. Asadi

Silicone Casting of the Chambers of the Heart and the Great Vessels....17
R. W. Henry, G. B. Daniel and R. B. Reed

A Study on the Preservation of Exhumed Mummies by Plastination....20
Zheng Tianzhong, You Xuegui, Liu Jingren, Zhu Kerming

Dissection and Plastination of the Human Cerebral Dura Mater with the Base of Skull....23
Gilles Grondin and Régis Olry

Student Participation in Plastination as a Learning Exercise in a Science Degree Embryology Unit....26
Gary Whittaker and Georgina Fyfe

(continued on page 2)

COVER PAGE: S10 Plastinated Human Dura Mater (see paper page 23)

TABLE OF CONTENTS

LITERATURE REVIEW

Thesis Review.....30
Régis Olry

Current Plastination Index - Updating.....31
Gilles Grondin, Régis Olry

ISP NEWS

ISP Members List.....32

ANNOUNCEMENTS

Practical Applications in Plastination.....38
Peter Cook, Russell Barnett

Instructions to Authors.....(inside back cover)

Presidential Letter

Dear fellow plastinators,

The field of plastination is going through a polarization into artistic, commercial, research and teaching branches. Moreover, has the expiration of Dr. von Hagens' U.S. patents led to the development of several new polymers.

Plastination has recently been used for the production of healthy and pathologically altered human specimens, that were exposed to the public in both Osaka and Tokyo, Japan as well as in Mannheim, Germany in connection with literature (e.g.: The dream of immortality) and music and dancing performances (e.g.: Is it possibly the death?). This exhibition called " The Human Body World" produced a worldwide discussion including statements about human dignity, violation of the sanctity of the soul and macabre mummification technique.

Plastination, however, has primarily been used for medical purposes, mainly for teaching students and members of medical professions as well as for gaining new results in medical research since years and this has finally led to the formation of the International Society for Plastination. Article II of the bylaws and constitution of the ISP refers to the ISP as a multidisciplinary organization, including persons within all fields of SCIENCE interested in the technique of plastination to produce material for TEACHING, RESEARCH or DIAGNOSTIC PURPOSES.

Although I do not want to judge the use of plastination for such exhibitions, I must state that from an anatomist's point of view the artistic and commercial exposition of dissected human cadavers may damage the reputation of anatomy departments and do not correspond to the bylaws of our society. People who donate their bodies to anatomy programs do this in order to support the education of highly qualified future doctors and to support medical professionists in learning and testing surgical treatments in the dead body before they touch and invade the living body by needles and scalpels. But they do not want to be sold to the public.

The announcement of several companies, to have new and cheaper polymers usable for plastination that could replace the Biodur™ polymers sound promising. However, as far as now those polymers have not been tested and led to the production of satisfying specimens. Moreover, there is no evidence that these companies have solutions for all the plastination procedures. That is why, I suggested to invite those companies to participate in the 9th International Conference on Plastination, show their products and results and face up the discussion.

There are many interesting new developments in the field of plastination and the 9th International Conference on Plastination in Trois-Rivières, Québec, Canada during July 5-10, 1998 will give you the chance to learn about both the standard and new and/or altered procedures, to learn about new polymers and equipment, to present and discuss your own results and last but not least ask the experts.

The sixth biennial meeting of the ISP on Thursday, July 9, will also offer all members of the ISP to vote for a new executive committee, that will lead the society through the next two years.

Thus, I strongly recommend that you come to Trois-Rivières to participate in the conference, that is hosted by our vice-president, Prof. Dr. Régis OLRY and our journal editor Gilles GRONDIN. They have established an excellent and interesting scientific as well as a wonderful evening and spouse program and I know that they are waiting for you eagerly and they will welcome and treat you with the greatest hospitality.

Finally, I want to thank the ISP members for their input in the society, especially via Email, and the Executive Committee Members for their support, especially Ronn WADE for providing us with the listserver and Gilles GRONDIN for pushing the quality and quantity of our journal.

Yours sincerely,

Andreas H. Weiglein

Editorial

From scientific popularization to voyeurism: what about exhibition of plastinated specimens?

Régis Olry

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As an introduction to this editorial, may I be allowed to tell you the story of a pupil of Jakob Christoph Le Blon: the French artist Jacques-Fabien Gautier-Dagoty (1716-1785). In the mid-eighteenth century, he invented (or improved) a technique of color engraving which was very successful in illustrating books of anatomy. Pierre Tarin and Joseph Guichard Du Verney, among others, called on Gautier-Dagoty's service for many anatomical plates. Some years later, the anatomical illustrations began unfortunately to lose their scientific content, and became more and more gruesome: the plates «do not have any more the slightest useful purpose in anatomy. The chromatic system only serves as a reverie with a sexual connotation on human body: the accurate definition of the figures is neglected on behalf of incongruous esthetic effects, of more and more insistent phantasmagoric digressions» (Rodari, 1996). Gautier-Dagoty really perfected a very attractive technique, but could no more differentiate between artistic and scientific anatomy on the one hand, and more or less questionable iconographic prowesses on the other hand.

Over two centuries later, the same story is maybe about to happen again. The numerous exhibitions of plastinated specimens give rise to controversy which brings back Gautier-Dagoty's difficult times to me. Many journals *(New York Times, Le Devoir...)* mention the uneasy feeling produced by some whole body plastinated specimens, which effectively belong much more to baroque anatomy than to science or scientific popularization (Olry and Motomiya, 1997a). In this short editorial, my aim is neither to question religious convictions, nor to reprove this kind of exhibition for the general public. I only would like to give rise to reflections on these events and their putative consequences.

Firstly, it has to be pointed out that most of visitors are very satisfied with the exhibition, and do not express the slightest scepticism at all (Olry and Motomiya, 1997b). Secondly, it is obvious that small plastinated specimens (heart, lungs, liver,...) are well accepted, including - maybe especially - those with pathological conditions (cardiac infarction, bronchogenic carcinoma, cirrhosis of the liver,...). In other words, every thing related directly to scientific popularization is welcome in the general public, and this kind of exhibition will probably have to be developped in the future. Unfortunately, many people may be shocked by other specimens, such as whole body plastinated specimens holding in their hand their own muscular system, abdominal viscera or gravid uterus. One of my colleagues, a French professor of anatomy, disapproved of the exhibition of such specimens: I only want to point out with this remark that not only bigoted churchwomen may take offense at them. In a democracy, every one has a right to express an opinion, and every kind of art has a right to be displayed. Some people will claim that such specimens should never be exhibited, whereas other people will point out the fact that these specimens were not displayed on the street, in full view of every body. Would it be reasonable to censor some specimens, but according to which principles?

Another point however is worth thinking over. The papers published in different journals all around the world mention this polemic, and we all have to hope that they will not cast a slur on the image of plastination in the general public.

Plastination is a wonderfull technique of preservation. As usual in science, the use which is made of it is dependent on every one's freedom of conscience.

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Mannheim Journal: Anatomy on Display, and It's All Too Human

Edmund L. Andrews

MANNHEIM, Germany - Until recently, this mid-sized industrial city wasn't known for much more than its Ice-hockey team. But that was before the Runner, the Muscle-man and the Expanded Body.

The three are among the displays at «Human Body World,» an exhibition on human anatomy at Mannheim's Museum of Technology and Work. The life-sized figures are posed in familiar human activities like running, standing or sitting, but unlike the specimens at a conventional science museum, the Runner and his numerous colleagues are real human corpses. Preserved through a process called «plastination,» the bodies, donated by volunteers, have been transformed into what the inventor of the process calls «anatomical artwork.»

And they have stirred up a debate across Germany over the boundaries of morality, art and science.

The Runner is frozen in the loping gait of a marathoner, stripped of almost everything except bones and muscles. Its outer muscles fly backward off its bones, as if the muscles were being blown by the wind rushing past.

The Muscleman is a bare skeleton that holds up its entire system of muscles, which looks like an astronaut's bulky spacesuit dangling on a hanger. The Figure with Skin retains all its muscles and organs, but its skin is draped like a coat over one arm. The Expanded Body resembles a human telescope, its skeleton pulled apart so people can see what lies beneath the skull and the rib cage.

Catholic and Protestant church leaders have denounced the exhibit as a breach of human dignity. The Premier of the state of Baden-Württemberg would like to shut down the exhibit. The local district prosecutor is trying to decide if he can bring criminal charges against museum officials.

Yet the show has also attracted heartfelt praise. Defenders say that, far from being macabre, the exhibition celebrates the wonder and the fragility of the human body in all its dimensions.

«I do not see this as a room full of corpses or as a hall of death,» said Gunther von Hagens, a medical doctor who is a lecturer in anatomy at the University of Heidelberg School of Medicine who invented the plastination technique and assembled the exhibit here. «What this does is build bridges back to your own body. When you look at the models, you can recognize yourself as a member of the human species. Your humanity becomes clear.»

More than 200,000 people have passed through the exhibit since it opened two months ago, and visitors now wait as long as three hours to get in. Upon leaving, a vast majority of visitors say the exhibit gave them a new appreciation of the human body. Many have even signed up as potential donors of their own bodies.

«It showed the human body as a wonder machine,» said Gisela Linde, an architect from Berlin who came to the exhibit at the insistence of one of her children, a medical student. «You can see the complexity and the mystery. It showed the humanity. I really would like to have stayed longer.»

Both the technology and the exhibit's often shocking impact come from Dr. von Hagens, a 53-year-old refugee from the former East Germany who is unfazed by accusations of being a real-life Dr. Frankenstein. Indeed, as he threaded his way through the packed crowd at the exhibit, he was more surprised to find himself besieged by people wanting his autograph.

«Just look at all the people coming here - and many of them came here full of skepticism,» he said. «But they find themselves fascinated and enthusiastic. That shows you that this exhibit is affecting them in an important way.»

Dr. von Hagens pioneered his preservation techniques for use in medical schools shortly after arriving in Heidelberg more than 20 years ago. Body parts are immersed in acetone chilled to 13 degrees Fahrenheit, and the water is removed from every cell. The water is then replaced with molten plastic material that later hardens. The parts retain their color and shape, though many organs end up looking like plastic.

Dr. von Hagens went on to become a virtuouso at displaying individual aspects of the body - the skin, the muscles, the digestive tract or even just the circulatory system. He also learned how to preserve human bodies in vertical and horizontal slices a quarter-inch thick.

But therein lies the controversy. While nobody questions the value of fashioning sophisticated cadavers for use by medical students, religious and ethical critics say Dr. von Hagens has crossed an important line by treating the human body as something tantamount to a sculptor's clay.

«The Mannheim exhibition fits somewhere between art and commerce, one in which the likely damage to taboos has been factored in as a cost,» said Johannes Reiter, a Catholic theologian and ethicist at the University of Mainz who serves on a commission that advises Chancellor Helmut Kohl on questions of ethics and technology. «He who styles human corpses as a so-called work of art no longer respects the importance of death.»

Catholic and Protestant church leaders from Mannheim have also vigorously protested the exhibition, and implored local government leaders to prevent it from even taking place. But while local government officials have been sympathetic, they have thus far been unable to come up with a valid legal objection to the show.

Dr. von Hagens argues that his exhibit gives people a new respect for the body. They can inspect the damage to a lung caused by smoking or to a liver shriveled by alcohol poisoning.

Yet he himself has invited criticism by referring self-consciously to his displays as «anatomical artwork.»

«I use the word art very cautiously, because it has come to mean business and entertainment,» he said as he strolled through the museum.

«What I mean here is an exhibit of the human anatomy that is both instructive and esthetic, an exhibit so exact that it represents a work of art.»

To that end, medical students from the University of Heidelberg have been paid to explain the anatomical ideas behind exhibits that often seem bizarre at first glance.

The Runner, for example, shocks many visitors, because the muscles look as if they have been stylized into some form of modern sculpture. But tour guides on hand say the real purpose is to let people see the many different layers of muscle.

«It you just looked at the surface, you would only see the outer muscles,» said Jens Kubitz, one of the students. «Here, you can see the lower muscles as well, the ones that help us keep our balance and work for us all the time without our even realizing it.»

By any measure, some of the exhibits are shocking. On one female corpse the stomach and womb have been slashed open to reveal a five-month old fetus. In a glass case at the center of the room, visitors encounter a row of plasticized infant corpses, including a pair of conjoined twins.

All the adult bodies that appear in the exhibit were donated by volunteers who knew what they would be used for, and the donors' identities have been protected. He does not accept the bodies of infants. Dr. von Hagens said the infants he plastinated for the exhibit were acquired from hospitals and medical schools. They were all preserved early in the century, he said.

Although he has been approached by anti-abortion groups to prepare plastinated fetuses for their use, he said he has refused to do so for fear of becoming embroiled in political battles.

Dieter Blumer, a schoolteacher who traveled more than 300 miles from the town of Bocholt on the Dutch border to see the exhibit, said, «Some of the exhibits were right on the edge.» He added, «But in the end, I would have to agree that the human body can be used for another useful purpose after a person dies.»

Dr. von Hagens said that he has not even begun to run out of ideas for new body displays. «I have already designed quite a few other specimens, but I wouldn't show them here because they would be misunderstood», he said.

(Reprinted from The New York Times, January 7, 1998)

Short History of Vascular Injections, with Special Reference to the Heart Vessels

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Key words: *Vascular injections, Coronary arteries, Venae cordis minimae, Lymphatics of the heart*

Abstract

Vascular injections of colored mixtures were probably not performed before the seventeenth century. They are intended to allow a more detailed description of arteries, veins and lymph vessels, but also to produce specimens to be exhibited in anatomical and natural sciences museums, usually after corrosion. This paper gives a summary of the development of vascular injection procedures and mixtures in the seventeenth and eighteenth centuries, with special reference to the injection of the heart vessels (coronary arteries, venae cordis minimae, and lymphatics).

Introduction

The knowledge of the course and ramifications of blood vessels was based for a long time on the dissection of non injected vascular systems. Only large vessels could therefore be described, for the small branches were usually cut off during the dissection. Galen recommended introducing a wooden probe into the vessels during the dissection, so that the knife could not damage their walls. This procedure was still in use in the seventeenth century. Covert Bidloo (1649-1713), among others, depicted wooden probes in the heart cavities on a plate of his famous 1685 treatise (figure 1). The problems with these probes were two in number. First, they could not be introduced into very small vessels. Second they were not flexible and therefore compromised the course and relationships of the vascular system. That is why it became necessary to develop vascular injection procedures on the one hand, and to find color injections mixtures on the other hand (table 1). In addition to the scientific aspect of these procedures (detailed anatomical description of the vascular system), vascular injections were also intended to produce long lasting specimens for anatomical and natural sciences museums which drew crowds in the eighteenth century.

Figure 1. Plate 9 of Bidloo's treatise, engraved by Gerard de Lairesse (1685). Wooden probes are introduced into the heart cavities to show their communications with the large vessels.

The development of vascular injection procedures

Vascular injections may have been performed by anatomists as far back as in the Middle Ages. Alessandra Gigliani, who assisted the famous Bolognese anatomist Mondino dei Luzzi (ca. 1275-1326) in his lectures, is sometimes regarded as the first one to have been successful in «injecting blood vessels with various colored substances» (Martin, 1934). However, no information could be found concerning the nature of these substances and the injection procedure. Moreover, this hypothesis has been rejected by most of historians of anatomy, who question Gigliani's biographical data (Wolf-Heidegger and Cetto, 1967; Olry, 1997).

Leonardo da Vinci (1452-1519) is known to have performed wax injections into the brain ventricles, and «injec-

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tions of a solidifying liquid into the body» (Cazort et al., 1996). We could therefore infer that he probably also used vascular injections to study the course of blood vessels and the morphology of the heart cavities although there is no definitive proof that he used vascular injection (O'Malley and Saunders, 1952; Huard, 1968; Kurz, 1992).

Though Andre Vesale (1514-1564) described in his 1543 treatise a U-shaped tube (siphon) to perform injections, it seems that he never used it for the injection of blood vessels (Kurz, 1992). Moreover, this instrument appears neither on the plate depicting the dissection and preparation instruments in the 1543 edition, nor on the frontispiece of the fifth 1604 edition. A detailed description of this «Sipho anatomicus» was made about two centuries later (1746) by the German anatomist Georg August Langguth (1711-1782) (figure 2).

In the mid-seventeenth century, the surgeon Wilhelm Fabricius von Hilden (1560-1634) used an injection apparatus composed of a cannula linked to a dried bladder. A funnel and two faucets allowed the filling of the bladder and prevented the back flow of the injected mixture from the vessels to the cannula (figure 3). Subsequently, many famous anatomists tried to improve on this kind of injection apparatus: Regnier De Graaf (1668), Francis Glisson (1677), Richard Lower (1708), Stephen Hales (1733-1734), Alexander Monro (1733), Johann Nathanael Lieberkuhn (1789) (figure 4), Ludwig Teichmann (1879), and Gustav Schmiedel (1930), among others.

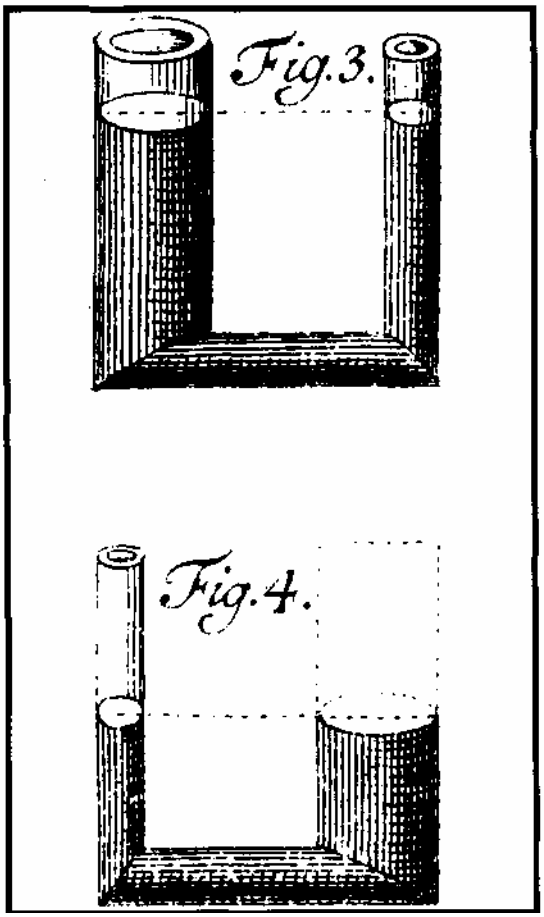

Figure 2. The «sipho anatomicus» by G. A. Langguth (1746).

The development of vascular injection substances

Many experiments were performed using various vascular injection mixtures in order to enhance the results (table 1). As far back as in 1522, Giacomo Berengario da Carpi (ca. 1460-1530) performed vascular injections with warm water, using a syringe. Thirty years later, Bartolomeo Eustachi (1520-1574) used the same procedure on renal arteries, and could observe the filling of the bladder.

However, the best vascular injection procedure results

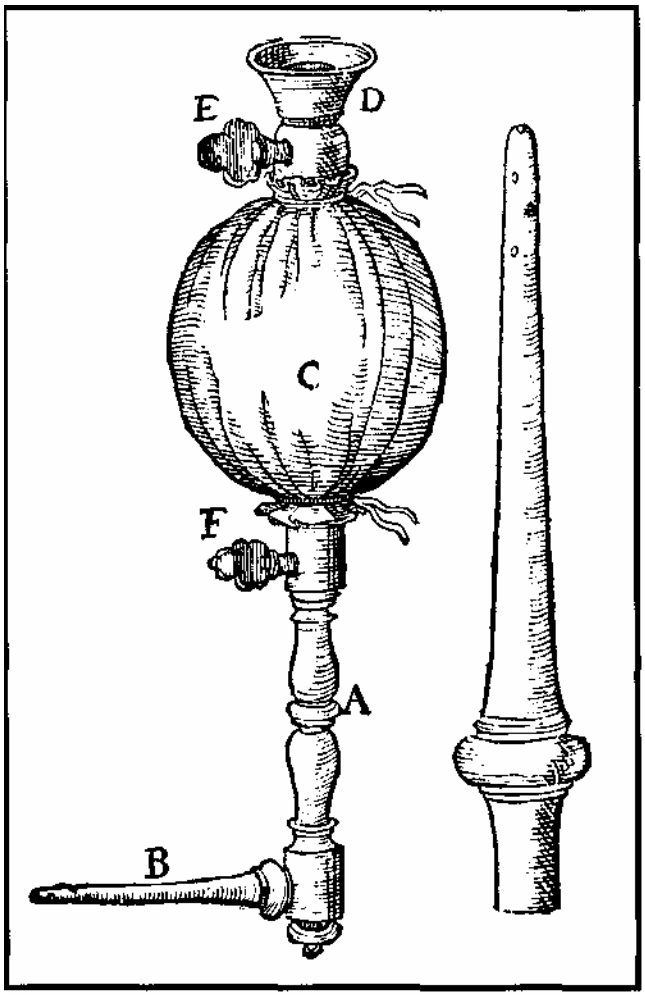

Figure 3. The injection apparatus described by W. F. von Hilden (1646). A and B: tube linked to a cannula. C: dried bladder. D: funnel. E and F: faucets.

were obtained by the Dutch anatomists Jan Swammerdam (1637-1680) and Frederik Ruysch (1638-1731). In 1672, Jan Swammerdam injected melted wax into the vessels of the uterus using a copper syringe (Fort, 1902). The specimens were so attractive that Frederik Ruysch decided to improve on the method. In the early eighteenth century, he was aknowledged as the «apostle of the injection technique* (Hagelin, 1989), and his striking specimens drew crowds in anatomical museums. Fontenelle said that «in a way, Ruysch's mummies prolong life, whereas Egyptian mummies only prolong death» (cited by Fort, 1902). The vascular injections of the specimens were so successful that Ruysch wanted to keep the composition of his injection mixture secret. He only called it «Materia ceracea». However, its composition was published twelve years after his death. It was composed of tallow, white wax, cinnabar, and «sometimes other substances, depending on the seasons* (Kurz, 1992).

In the late seventeenth century, Homberg injected blood vessels with a mixture of lead, tin and bismuth (1699); unfortunately, the results were disappointing. Finally, gelatin was used for the first time in vascular injection by Ronhaut, the surgeon to the King of Sardinia (1718).

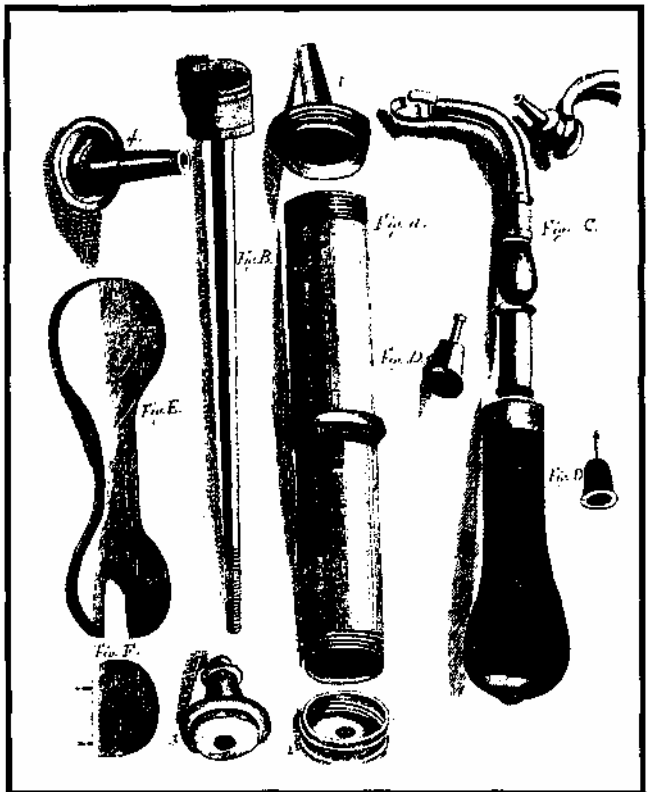

Figure 4. Syringes for vascular injections after J. N. Lieberkuhn (1789).

Heart vessels injections

A wonderfull specimen of injected coronary arteries was depicted in Frederik Ruysch's Opera omnia (1726) (figure 5). This specimen shows the ascending aorta, the right coronary artery and some of its ventricular branches, and the left coronary artery with its division into anterior interventricular and circumflex arteries. Numerous atrial rami are to be seen, arising from both coronary arteries. A large left conus artery is depicted, leaving the anterior interventricular artery near its start, and anastomosing on the conus with that of the right coronary artery.

The discovery of the opening of the venae cordis minimae into all cardiac cavities, is commonly attributed to the German anatomist Adam Christian Thebesius (1708). However, the existence of these minimal veins (Aho, 1950), which are more difficult to demonstrate than larger cardiac vessels, was first reported by Raymond Vieussens in a letter addressed to M. Boudin in 1706. Raphael Bienvenu Sabatier gives a detailed account of Vieussens' procedure in a memoir of 1792. For this experiment, Vieussens used two human hearts. He tied both venae cavae, the pulmonary trunk and the aorta. Then, he injected slowly a saffron tinting into the left coronary artery, and could observe that both atrial and ventricular left cavities became full of yellowish liquid. Moreover, the right cavities remained uncolored. Thebesius only confirmed the existence of these veins in his Latin dissertation (1708), by injecting water and colored wax into the cardiac veins.

Though Olof Rudbeck (1630-1702) discovered the subpericardial lymph vessels as far back as 1653, the systematization of the lymphatics of the heart was not understood before the second half of the nineteenth century (for the history of injection procedures of lymphatics in general, see Olry and Motomiya, 1997). The subendocardial lymph network was discovered by Eberth and Belajeff (1866), the epicardial ventricular lymph network by Sappey (1874), and the epicardial atrial lymph network by Rainer (1907) and Mouchet (1909).

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Table 1. Some landmarks in the history of vascular injection.

Author	Date	Substance	Equipment
A. Gigliani (?)	Early XlVth century	Various colored substance	7
L. da Vinci (?)	1504-1507	Wax	7
G. B. da Carpi	1522	Warm water	Syringe
A. Vesale	1543	7	Siphon
W. F. von Hilden	1615	7	Cannula linked to a bladder
J. Swammerdam	1672	Melted wax	Copper syringe
G. Homberg	1699	Lead, tin, bismuth	Pneumatic apparatus
R. Vieussens	1706	Saffron tinting	?
A. C. Thebesius	1708	Water, colored wax	?
F. Ruysch	1726	"Materia ceracea"	7
Ronhaut	1718	Gelatin	?
G . A. Langguth	1746	7	Sipho anatomicus

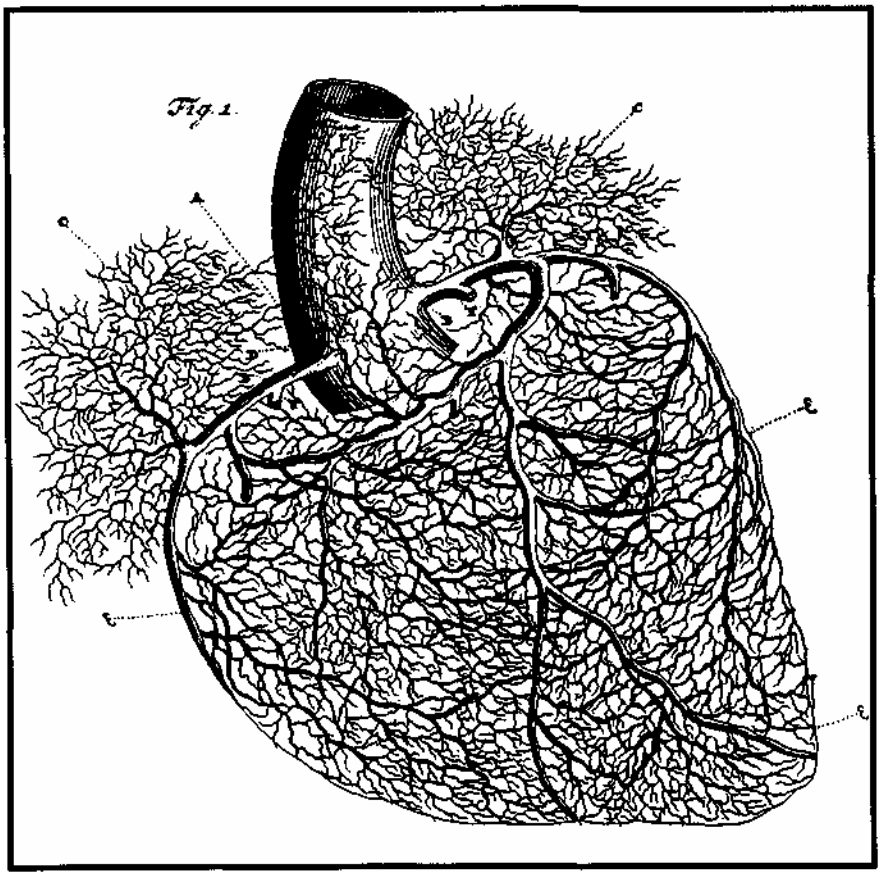

Figure 5. Vascular injected specimen of the heart by F. Ruysch (1726).

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Plastination of Three Dimensional Brachial Plexus with P40

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(received January 6, accepted March 5, 1998)

Key Words: *Brachial plexus, P40*

Abstract

This study intends to present a new aspect in plastination with P40, not only in processing brain slices, but also in plastination of three dimensional structures. We decided to make this attempt with nervous tissus and choose to plastinate human brachial plexuses. Two plexuses were removed from a fixed body, from the dissection room. After dehydration, they were immersed and impregnated with P40. The main problem in curing P40 is that it should be done under UV-light and in a closed, airless chamber, otherwise the surface of the plastinated specimen remains sticky. Curing was therefore performed by using UV-light and simultaneously keeping the specimens under vacuum.

Introduction

The P40 technique is used for brain slices plastination and shows a very good differentiation between the gray and white matter (von Hagens, 1994; Barnett, 1997). While working with P40 we considered using it for plastination of three dimensional structures. As P40 has proved hitself successful with brain slices, we considered that a nervous structure would fit the purpose of this experiment best, so we decided to plastinate brachial plexuses. Nerve plexuses have been plastinated before with P35 (Weiglein and Bahadori, 1996) but these specimens were prepared between glass and did not have the three dimensional aspect that we were looking for. It is also well known that brains and nerves can be plastinated by using S10 (Resch, 1989; Riepertinger, 1989; Haffajee, 1996) however color is often not preserved and at the end nerves will sometimes appear gray or brown. With the P40 a better color preservation may be achieved.

Materials and Methods

Fixation and Dissection

The brachial plexuses were obtained from a fixed cadaver, from the dissection room. The cadaver has been fixed with a solution containing 5% formalin; 3% phenol and 92% water by means of injection via the femoral artery. Dissections were performed as follows: we removed the clavicle. Each plexus was dissected starting at the proximal ends and colored cords were attached to the roots as they were isolated. After dissecting the axilla, the plexus was removed, and immersed in 5 % formalin for one week at room temperature.

Rinsing in running water

The specimens were rinsed overnight in tap water before the dehydration process. They were then precooled at +5°C in order to avoid the formation of ice crystals (von Hagens, 1985) when placed in cold acetone.

Dehydration

Dehydration was performed by the freeze-substitution method in acetone at -25°C. Each specimen was immersed in a container with 3 liters of acetone. The acetone was changed every 3 days. Two changes were necessary and the final concentration remained at 98.8% after one week.

Impregnation

Dehydration being completed, the brachial plexuses were impregnated with BIODUR P40 (Biodur, Rathausstrasse 18, 69126 Heidelberg, Germany). The resin was first precooled in the same freezer which had been used for the dehydration of the specimens at -25°C to avoid shrinkage. The plexuses

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were then placed in P40 (the resin level should be 2 cm above the specimen) and the container placed in a refrigerator at +5°C overnight. Next morning, the container was brought at room temperature and impregnation started immediately. Forced impregnation began with an adjustment of the pressure in the chamber at 180 mmHg (240 mbar). During the whole day the vacuum was adjusted down to a pressure of 10 mmHg (13 mbar). Vacuum increase depended on the formation of impregnation bubbles. At room temperature the impregnation took approximately 10 hours.

Curing

Some special arrangements had to be made for curing. First the impregnated plexuses were removed from the P40 and drained for 10 minutes laid flat on a mesh. The next step was to rearrange and expand each branch of the plexuses to their natural shape. In order to obtain a three dimensional form of the plexus, each specimen was first placed on a cork plate covered with polyethylene foil. At this time the plexus was soft, so that the spinal roots, at the proximal end of the specimen, were put in the right position using stainless steel nails (root C-5 at the top, then C-6, C-7, C-8, and at the bottom T-l). The trunks of the plexus were separated by using foam pieces also covered with polyethylene foil. The same procedure was used for the separation of the divisions, cords and branches of the plexus. At it's distal end, the main branches were kept in position by using stainless steel nails. Other small branches were pinned in the right position with needles (figure 1).

After this procedure was finished, the whole cork plate, including the specimen, was placed in a vacuum chamber. Next it was necessary to create maximum vacuum (the ideal pressure inside the chamber should be 1 mmHg). Polyester resin will not cure and the surface ot the specimen will remain sticky if air remains in the vacuum chamber (Kirk-

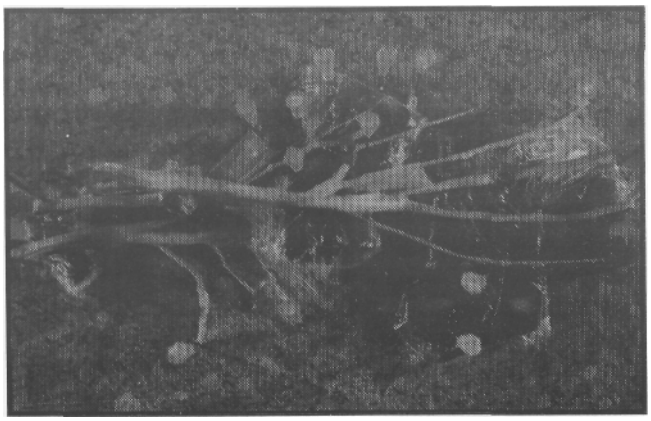

Figure 1. Brachial plexus disposed on a cork plate for the first stage of curing.

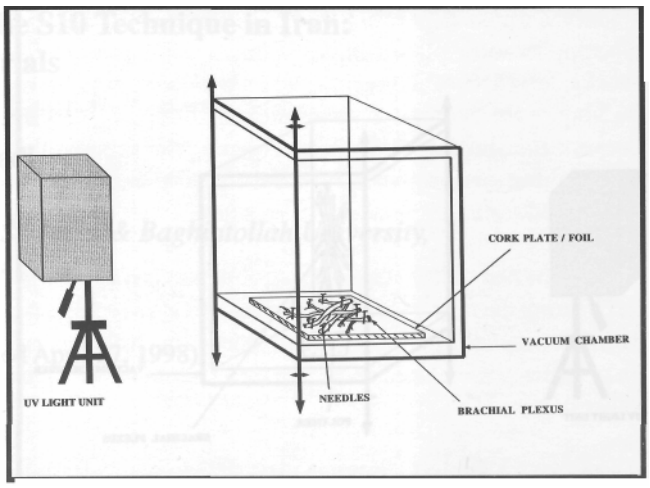

Figure 2. Brachial plexus on cork plate placed inside the vacuum chamber, facing the UV-light unit for the first stage of curing.

Othmer, 1996). An UV-light unit (200 kW) was placed in front of the vacuum chamber (figure 2). The distance between the specimen, in the vacuum chamber, and the UV-light was 40 cm.

After 15 minutes, the plexus was removed from the vacuum chamber. The cork-foil plate was removed and the plexus suspended with a wire inside the vacuum chamber. Resin drops found on the surface of the specimen were easily removed with a scalpel. The specimen was put back in the vacuum chamber and curing under vacuum and UV-light continued. After one more hour, the surface of the specimen was cured enough to permit the foam pieces and the needles to be removed (figure 3). Complete curing took about 5 hours. In the first two hours the vacuum chamber was opened every half an hour and the specimen turned around, so it would cure from all sides. Every time the vacuum chamber was opened, the specimen was smeared with P40. After two hours the vacuum chamber remained closed until the specimen was completely cured.

Results

Specimens prepared with this method retain their natural three dimensional aspect with a very good color preservation (figure 4)

Discussion

We know that the polymerization of polyesters happens in two phases: first a gel phase and after that the hardening phase (Arpe et al, 1992). Our experiences with P40 samples in vacuum exposed to UV-light showed that the polymer becomes a gel after 15 minutes.

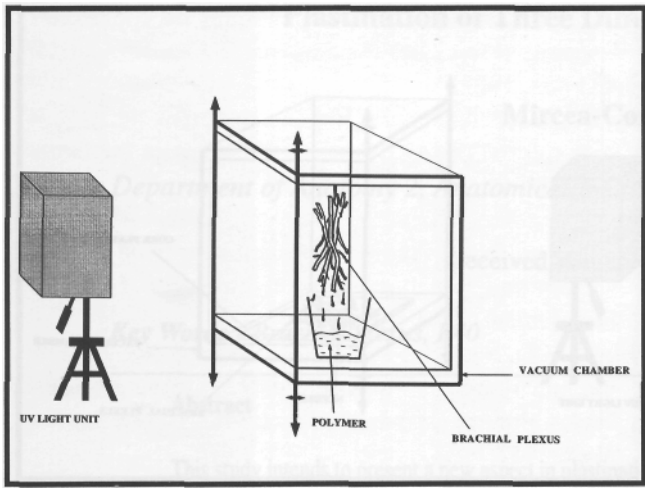

Figure 3. Brachial plexus suspended inside the vacuum chamber for the final stage of curing.

Plastinating a brachial plexus with P40 has advantages but also disadvantages. As an advantage the processing time is short. The immersion and impregnation time with P40 takes only one day, while by the S10 method the impregnation time takes up to three weeks. An other advantage is that the cost of the material is reduced because P40 is cheaper than S10 (1 kg of Biodur P40 cost 35 DM while 1 kg of Biodur S10 cost 67 DM). Color preservation is also better by using P40.

Disadvantages occur in the curing stage where one must have a good vacuum pump to reduce the pressure down to 1 mmHg. An other disadvantage is that you must supervise the curing very carefully, in order to open the vacuum chamber and turn the specimen around. As a disadvantage you may consider that the P40 plastinated plexus will be solid but fragile in comparison with the S10 method that produces flexible specimens.

This study tries to find some new applications in the field of plastination by using P40. This method may seem a little complicated but is certainly worth mentioning. We are actually developping this method for the plastination of dissected brains, in order to get a better differentiation between gray and white matter. Results will be presented later in an other paper.

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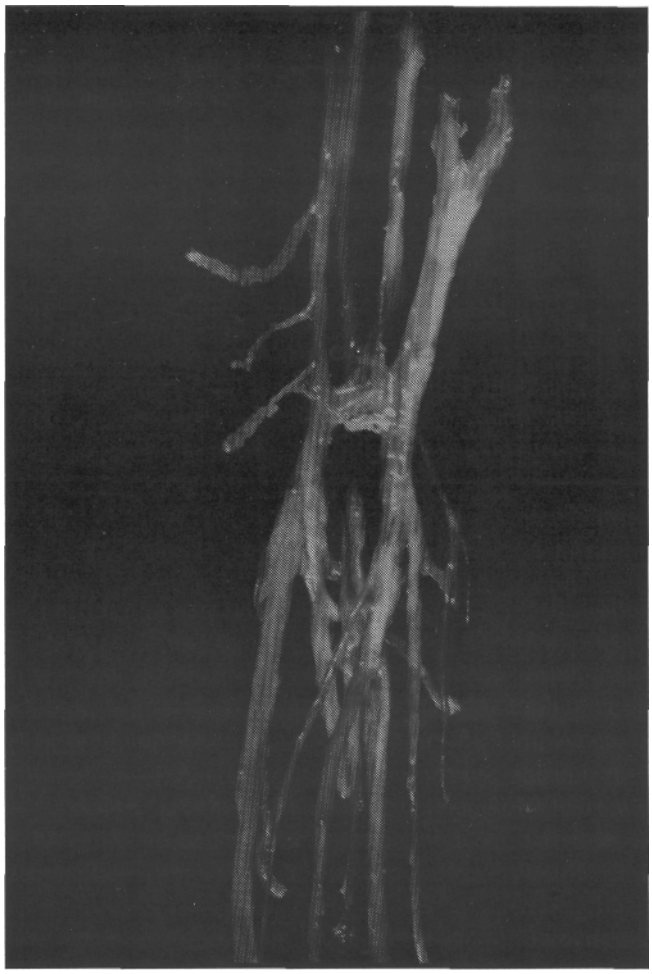

Figure 4. Three dimensional brachial plexus prepared with the P40 polymer.

Plastination of Sturgeons with the S10 Technique in Iran: the First Trials

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(received March 5, accepted April 27, 1998)

Key Words: *Polymer S10, Fish*

Abstract

Ten sturgeons from three species *(Huso huso; Acipenser persious and Acipenser stellatus)* were plastinated according to the standard S10 technique. They were primarily fixed in 5% formaline. After dehydration by the freeze-substitution method, they were submerged in silicone for 24 hours and forced impregnated at -25°C for four weeks. They were finally pre-cured in an oven at 40°C for two days and cured with S6. The plastinated fishes are perfectly preserved.

Introduction

Sturgeon, also called caviar fish, are one of the most important fish in the world because of the great value of its eggs (caviar), and its skin which is largely used in leather industry to produce high quality bags. Because of unregulated fishing and excessive captures, this precious representative of the chondros fish group is now in danger of disappearing (Vlasenko, 1994; Pourkazemi, 1997) from its most important habitat in the Caspian sea (named Khazar in Persian) located north of Iran.

In this paper, the complete procedure, carried out in the department of anatomy of Iran University of Medical Science, to plastinate sturgeons will be stated.

Materials and Methods

Ten fresh sturgeons (weight 350-3000g) were obtained from the Rasht International Sturgeon Research Institute and plastinated according to the standard S10 technique (von Hagens, 1985).

Fixation

Fresh fish were fixed, by injection and immersion, in 5% formaldehyde for eight weeks at room temperature. A probe was inserted in the gills for better diffusion of the fixative solution in their bodies. They were then rinsed in cold tap water over night, in order to remove the excess formaldehyde, and cooled to 5°C before being dehydrated.

Dehydration

The specimens were dehydrated by the freeze substitution method (von Hagens, 1985; von Hagens et al., 1987). They were submerged in the first bath of 92% acetone at -25°C for ten days. They were then transfered in a second bath of 97% acetone at -25°C for another ten days. The fish were finally submerged in the third bath with 100% pure acetone at -25°C for ten more days. For each acetone bath, the purity of the acetone was monitored with an acetonometer at 20°C. The acetone purity after the third bath was over 99.5%. Dehydration was then considered complete.

Immersion

The fish were immersed in a mixture of S10/S3 (100:1) for 24 hours at -25°C. Vacuum was applied to the polymer mixture 24 hours before the immersion of the specimens.

Forced Impregnation

In the large fish, small incisions (1 cm) were performed

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under the trunks to permit better penetration of the polymer. Specimens were placed under vacuum condition for four weeks, at -25°C. The pressure was slowly decreased down to 5mm of Hg. Slow decrease of pressure (Table 1) helped to prevent the shrinkage of the specimens. The acetone bubbles coming up on top of the silicone mixture were carefully monitored for adjustment of the vacuum.

At the end of this stage, the vacuum pump was switched off. During the next 24 hours, pressure was slowly increased to the atmospheric pressure and the specimens, still immersed in polymer, were placed at normal room temperature for another day.

Table 1. Impregnation schedule.

PRESSURE	PERIOD OF TIME
85mmHg	1 day
75mmHg	2 days
62mmHg	3 days
5O mmHg	4 days
40mmHg	2 days
3O mmHg	3 days
20mrnHg	2 days
lOmmHg	1 day
7mmHg	1 day
5 mmHg	7- 10 days

Curing

The slow curing method was used for polymerization.

Procuring

After forced impregnation, the specimens were removed from the S10/S3 and placed on a grid to drain the excess polymer from their surfaces. They were then placed in an oven at 40°C for two days.

Gas Curing

The specimens were placed on a grid and exposed to S6 (gas cure) vapors for 3 days at normal room temperature. A small circulatory pump was used to bubble air through the S6 which accelerated the curing of the specimens surfaces.

Results

Perfectly preserved sturgeons (figures 1 and 2) were obtained with the standard S10 plastination technique. No noticeable shrinkage was observed on any of the specimens. Compared with other techniques, such as taxidermy, plastination provided better specimens. They seem more natural, are more flexible and can be easily carried and manipulated by the students with less risk of being damaged. They can be preserved while retaining all of their internal structures, even the viscera. They can also be partially dissected to show internal structures for anatomical studies. The size of specimens to be plastinated can be adapted to the dimensions of the impregnation bath chamber.

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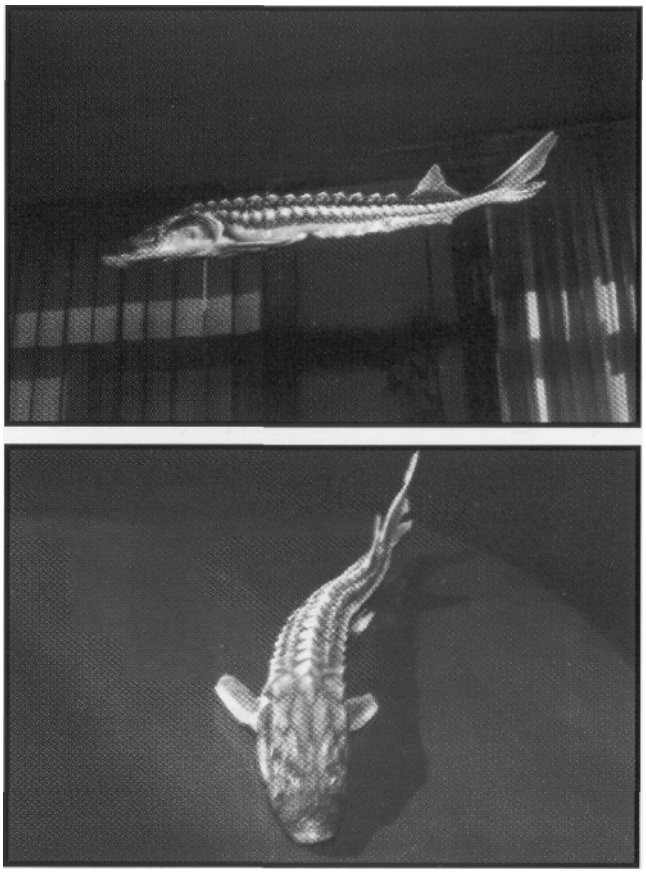

Figures 1 and 2. 39 cm (top) and 34 cm (bottom) sturgeons plastinated showing details of external surfaces.

Silicone Casting of the Chambers of the Heart and the Great Vessels

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(received April 9, accepted April 28, 1998)

Key words: *Cast, Heart, Ventricles, Silicone*

Abstract

Orientation of the overlapping chambers of the heart is difficult for first year veterinary medical students to conceptualize and confounding when attempting to determine ventricular volume using imaging techniques. To better visualize and understand the spatial relationship between the ventricles, silicone casts of the heart and great vessels were made from unembalmed sets of heart and lungs. The major vessels of the heart were either ligated or cannulated for silicone injection. Room temperature vulcanizing silicone was activated, colored and injected until the cardiac chambers were filled. After hardening, the specimens were first macerated in boiling water and maceration was completed in 5% hydrogen peroxide. A highly durable, anatomically precise replica of the cardiac chambers, valves and great vessels was thus obtained for student instruction and image analysis.

Introduction

Conceptualization of the orientation of the cardiac chambers and their overlap can be difficult for first year veterinary medical students. The overlapping chambers and their spatial relationship to each other are difficult concepts to master before one can interpret diagnostic images of the heart. The overlapping chambers can also result in errors in quantitating nuclear medicine images of the heart. To aid understanding of ventricular overlap and to determine the actual overlap of the ventricles, silicone casts of the cardiac chambers were made from en bloc heart and lung specimens. Silicone has been used for casting of various cavities since 1966 (Frank and Yoder).

Materials and Methods

Specimen preparation

The heart and lungs were removed as a unit from 40 pound canine cadavers. The descending aorta (proximal to its first intercostal branch), brachiocephalic trunk, left subclavian artery and cranial vena cava were ligated and transected distal to the ligatures. The caudal vena cava was transected near the diaphragm and cannulated with appropriate sized tubing. The left caudal lobar pulmonary vein was incised and cannulated with appropriate sized tubing directed toward the left ventricle.

Two room temperature vulcanizing (RTV) silicone polymers were used for this experiment [Silastic E RTV (Dow Corning, Midland, MI, USA); and P45 (Silicone Inc., High Point, NC, USA)] The polymers with their respective hardeners were mixed at a ratio of 10:1. The silicone was divided into 2 aliquots and colored, pink or blue, by adding color paste (Biodur, Heidelberg, Germany) until the desired color was achieved. Silicone injections were accomplished using catheter tip 60 ml syringes. Approximately 100 ml of pink silicone was injected into the left side of the heart via the cannulated pulmonary vein. Approximately 12Q_ml-of blue silicone mix was injected into the right side of the heart via the caudal vena eava. Injection volume was determined sufficient when the silicone was observed filling the proximal ends of the pulmonary vessels. To maintain proper alignment of the ventricles, 3 applicator sticks were pushed at diverging angles through the left ventricular wall and its silicone

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filled chamber, through the interventricular septum, into the silicone of the right ventricle and finally through the wall of the right ventricle.

Curing

In order to maintain the pulmonary vessels in proper anatomical position, the trachea was cannulated and laboratory air was utilized to inflate and maintain inflation of the lungs in normal inspiratory anatomical position until the lungs were dry and the silicone had cured (24 hours).

Maceration

Once the polymer was cured, the specimens were placed in boiling water for 8 hours until most of the tissue was eroded away. A high pressure hose was used to remove the majority of the remaining tissue. Final tissue removal was accomplished by submersion of the cast in 5% hydrogen peroxide until the specimen was free of tissue debris.

Results

A highly durable, anatomically precise replica of the cardiac chambers , valves and great vessels was obtained (figure 1).

Discussion

Silastic E RTV has excellent tensile strength which produces a durable specimen and molding qualities which produce an intricate, detailed cast. Of the many polymers which we have tried for casting (Henry, 1993a, b) both Silastic E RTV and P45 produce high quality casts. These casts were used for study of the heart and great vessels along with silicone-plastinated whole hearts and silicone-plastinated valve preparations by our first year veterinary medical students.

Casts were also used to aid the research effort of radiology faculty. A common nuclear medicine study of the heart is the radionuclide ventriculogram. This study is acquired following equilibration of a blood pool agent, "Technetium, labeled to red blood cells (Sisson et al., 1989; Daniel et al., 1993; Daniel, 1996; Daniel and Bright, 1997). The gamma camera records the distribution of the radiolabeled blood cells within the body. For cardiac imaging, the gamma camera creates images of the blood pool of the heart. During a cardiac cycle, the blood volume in the ventricles decreases from diastole to systole. Since the ^{99m}Tc-RBC's are in equilibrium with the blood pool, changes in blood volume correspond on changes in radioactivity recorded by the gamma camera. By recording the changes in activity in the cardiac chambers during a cardiac cycle, volume curves can be created from which indices of heart function are derived. The canine cardiac chambers overlap each other and determining the best camera position to separate the various chambers is difficult. The cast of the heart is an anatomic 3-D representation of the cardiac chambers as seen on the nuclear medicine images (figure 2). The cast was used to determine the best camera position with which to view individual cardiac chambers. By imaging the cast from both sides and then merging the two images (figure 1), the extent of ventricular overlap was readily discernible which allowed for extrapolating calculations of radionuclide imaging results.

Acknowledgment

The authors wish to thank Mr. Larry Janick for his help with this project.

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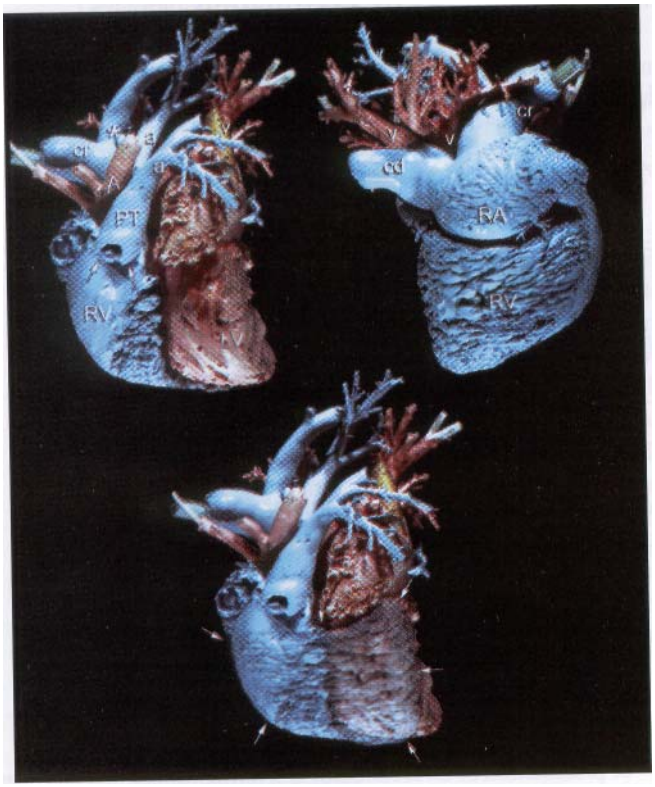

Figure 1. Silastic E RTV cast of cardiac chambers and great vessels. Upper right - As viewed from the right side; Upper left - As viewed from the left side (arrows - sinus of pulmonic valve);

Lower - Left view of cast with right ventricle (outlined by arrows) superimposed over the left ventricle, a - pulmonary artery, A - aortic arch, cd - caudal vena cava, cr - cranial vena cava, LV - left ventricle, PT - pulmonary trunk, RV - right ventricle, * - azygos vein.

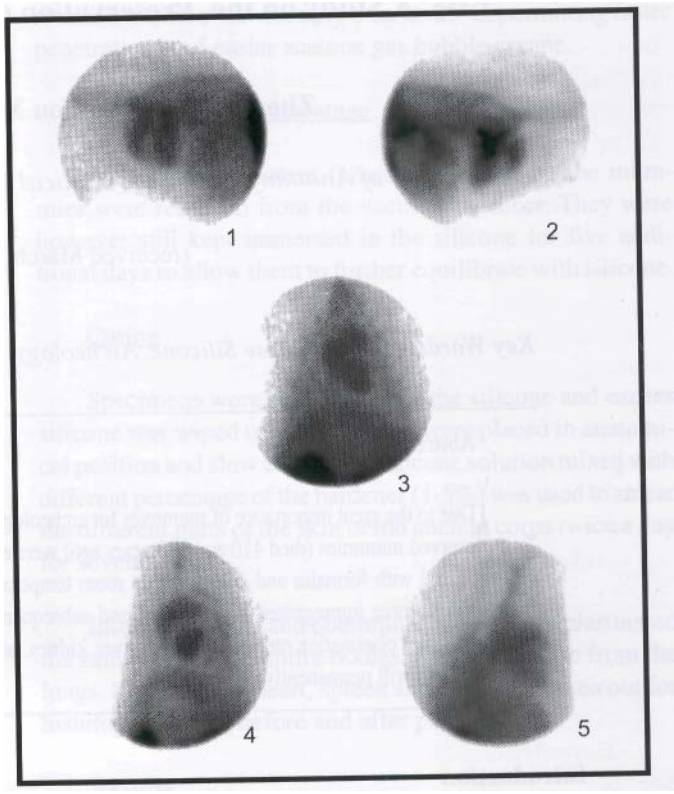

Figure 2. Radionuclide ventriculograms of the canine heart. 1 - Left lateral, 2 - Right lateral, 3 - Ventral, 4 - Ventral 30° left lateral oblique, 5 - Ventral 30° right lateral oblique.

J lnt Soc Plastination Vol 13, No 1: 20-22, 1998

A Study on the Preservation of Exhumed Mummies by Plastination

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(received March 7, accepted April 14, 1998)

Key Words: *Su-Yi Chinese Silicone, Archeology, Paleopathology*

Abstract

Due to the great importance of mummies for archeological research, methods have to be developed to preserve these specimens. Two preserved mummies (died 410 and 380 years ago) were exhumed and plastinated to avoid deterioration from exposure. They were first re-fixed with formalin and dehydrated at room temperature in a graded series of acetone solutions. The corpses were then pre-impregnated, force impregnated with silicone and subsequently cured all at room temperature. Histological studies were performed before and after plastination on pieces of lung, liver, kidney, heart, spleen and skin. Plastination improved the color and flexibility of the mummies and will permanently preserve them.

Introduction

Mummies have an invaluable value for academic research of our national culture. Extensive research studies are conducted to develop methods for the preservation of these corpses. There are two types of mummies: dry type and wet type. For the dry type most scientists prefer to keep them in a dry atmosphere, but for the wet type, scientists must dry them before keeping them in dry conditions or just immerse them into bath of preservative solutions. The wet mummies are considered more valuable than the dry ones. Immersing bodies into a bath of formalin is also not considered like the ideal method of long-term preservation. With limited technology in hand, some scientists suggest to keep these mummies underground and to stop exhumating them until an ideal long-term preservation technique has been developed and is available.

Plastination is a technique for permanent preservation of biological specimens (Bickley et al., 1981; Bickley and Townsend, 1984; von Hagens et al., 1987; Dawson et al., 1990). The plastinated specimens retain their original surface relief and cellular identity down to the microscopic level (von Hagens et al., 1987; Grondin et al., 1994). Plastination technique is suited for anatomy, zoology as well as for biologically oriented museums. To our knowledge, only one case of plastination of an archaeological human specimen has been reported (Wade and Lyons, 1995). In our laboratory, we successfully plastinated two ancient (400 years old) Chinese corpses, through fixation, dehydration, pre-impregnation and forced impregnation (Zheng et al., 1998).

Materials and Methods

Case 1: ancient corpse discovered near Zhengjaing in July 1997, male age 45, died 410 years ago. The skin of the limbs was dry, but the thorax wall and abdominal wall were still wet and flexible.

Case 2: ancient corpse discovered near Canton in 1992, male age 49, died 380 years ago. The skin of most parts of the body except the back was wet and flexible.

We do not know what methods were used at that time to preserve these bodies (Xu and Hu, 1996).

All internal organs within the thorax and abdominal cavities of these two mummies were removed. The bodies and internal organs were fixed by immersion in 7% formalin for 1 month at room temperature, then kept in a bath of 5% formalin at room temperature (2 months for case 1 and 5 years for case 2).

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Dehydration

Dehydration of the bodies was performed at room temperature in a graded series of acetone solutions of increasing concentration of 60%-70%-80%-90%-100% foe more than 8 baths.

After fixation the specimens were rinsed in running tap water for 4 days in order to remove excess formalin. They were then transferred to a 60% solution of acetone. After thorough mixing of the acetone bath with the immersed mummies, an acetonometer was used to monitor the acetone concentration every day. Once the acetone level was stable, the mummies were moved to the next higher concentrated acetone solution. In this manner, the mummies were gradually brought to the 100% acetone bath. When reading remained at 100% for 5 days we were sure that dehydration was completed and that the mummies were ready for impregnation.

Impregnation

This process was divided into three stages, all done at room temperature.

1. Pre-impregnation stage

The mummies were moved from the 100% acetone bath into the Su-Yi Chinese Silicone bath (Su-Yi Plastination factory, Nanjing, China). All parts of the bodies were completely submerged into the silicone solution for 7 days. They were moved around and turned over every other day to allow the acetone and air bubbles to escape and the corpses to equilibrate with the silicone.

2. Intermittent forced impregnation stage

After the initial period of equilibration, the mummies were transferred into a vacuum chamber and the intermittent forced impregnated procedure was started. Each working day, the vacuum was re-established and the pressure slowly decreased. At the end of the working day the vacuum was released and the chamber opened to allow the mummies to be moved around to relax them and facilitate further equilibration with the silicone. The pressure was decreased slowly over a period of 2 weeks. The vacuum was monitored by a manometer, and the progress of impregnation checked by observing the release of acetone gas bubbles from the surface of the bodies. The acetone gas bubbles rose slowly to the surface of the Silicone. Overtime the pressure was gradually lowered to 10 mbar and the vacuum maintained for 3 more days until no more acetone gas bubbles appeared. This indicated that no more acetone remained in the mummies.

We have observed that at room temperature the silicone retains a much lower viscosity than at -25°C, permitting faster penetration, and easier acetone gas bubble escape.

3. Post-impregnation stage

After the intermittent forced impregnation, the mummies were removed from the vacuum chamber. They were however still kept immersed in the silicone for five additional days to allow them to further equilibrate with silicone.

Curing

Specimens were removed from the silicone and excess silicone was wiped off. All the parts were placed in anatomical position and slow cured. Old silicone solution mixed with different percentage of the hardener (1-5%) was used to smear the different parts of the skin of the ancient corps twice a day for seven days.

Internal thoracic and abdominal organs were plastinated the same way as the entire bodies. Pieces of tissue from the lungs, liver, kidney, heart, spleen and skin were taken out for histological study before and after plastination.

Results

After plastination the mummies retained their original shapes but their weights increased. The colors appear better than before (figure 1). The soft tissues remain flexible and the specimens present no smell and no toxicity. The surfaces are dry, without oozing of remnant silicone and can be touched by bare hands. These mummies can now be easily kept for a long period of time without special care.

The internal organs within the thoracic and abdominal cavities retained their original shape and the colors are also much better than before the plastination process. The soft tissues are still flexible and it was possible to expand the cavities of the alimentary canal by air-injection (figure 2). The surfaces are dry and can be handled without gloves.

During the histological study, before and after plastination, we found some red cells in the lung tissue of one of the mummies. The morphology of these 400 years old red cells has been preserved and looks exactly like fresh ones (figure 3).

Discussion

The preservation of the valuable mummies is a complex problem. Many years of research have been dedicated to this subject. Even after all these years of work by many scientists, there are still no ideal methods or techniques to preserve the exhumed mummies.

We have used the technique of plastination to preserve two exhumed 400 years old mummies and acheived good results. Now it will not be necessary to dry the wet type mummies or immerse them into a bath of preservative solution. Using the plastination technique, the mummies can be preserved easily for a long time without special care. After plastination the weight of the mummies is increased which indicates that the silicone has penetrated down to the tissues of the specimens.

We were very excited to find some red cells in the lung tissue of one of the mummies. The morphology of these 400 years old red cells has been preserved. We do not know how they could have been preserved so well and which methodologies were used for keeping these bodies from decay. It should be another research subject.

Acknowledgment

The authors wish to thank Ms. Dan Hua Lian for help in histological study and Mr. Chen Yu Lian for his help in photography.

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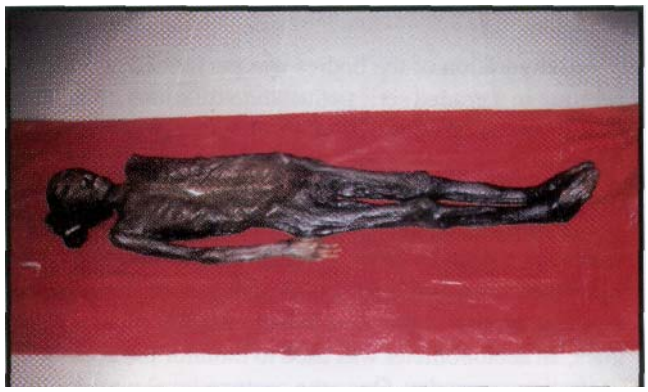

Figure 1. The Chinese mummy (after plastination).

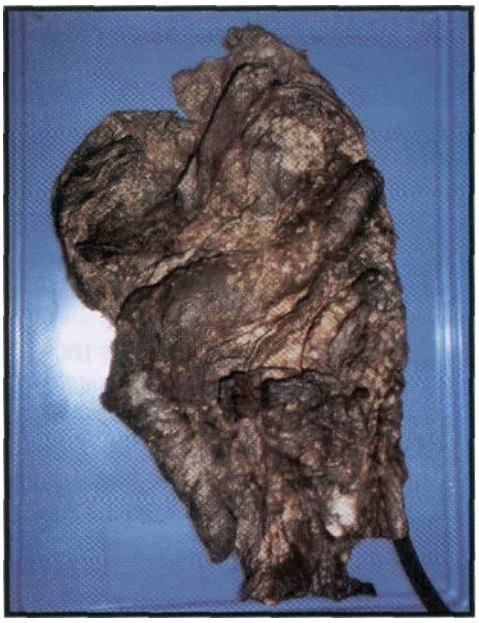

Figure 2. The cavity of the alimentary canal was expanded by air injection (after plastination).

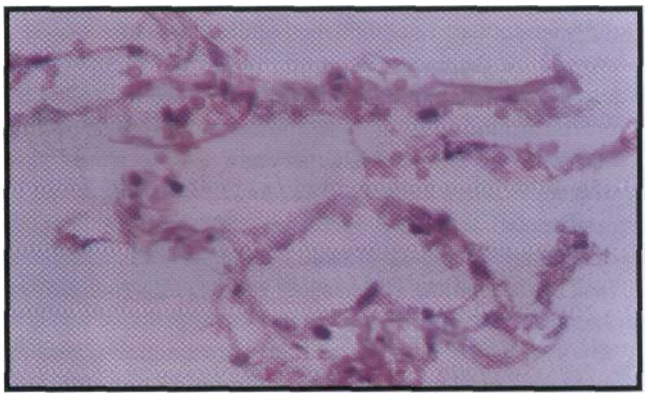

Figure 3. Red Cells found in the lung tissue of one mummy (after plastination).

Dissection and Plastination of the Human Cerebral Dura Mater with the Base of Skull

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(received March 10, accepted April 23, 1998) ***Key Words:*** *Meninges, Cranial Dura Mater, Falx Cerebri, Tentorial Incisure, Polymer S10*

Abstract

The aim of this study was to produce a plastinated specimen of the human cerebral dura mater with the base of skull, showing its morphological and topographical features. The authors give a detailed account of the dissection procedure to obtain a very helpful specimen in neuroanatomical and neurological curricula. Plastination of the specimen preserved the consistency of the meninges, and allowed a good understanding of its structure and different septa.

Introduction

The place of plastination in neuroanatomical pedagogics is well documented (Holladay and Hudson, 1989; Resch, 1989; Purinton, 1991; Weiglein, 1993, 1997; Magiros et al., 1997). However, the morphology and relationships of the meninges are also of outstanding importance in the teaching in medicine and allied sciences: circulation of the cerebrospinal fluid from the apertures of the fourth ventricle to the arachnoid granulations, location of the main cranial dural venous sinuses, infra or supratentorial topography of the main components of the central nervous system in relation with the tentorium cerebelli, distinction between extradural and subdural hemorrhages, transtentorial herniations. Specimens of the cerebral dura mater are therefore very helpful to neuroanatomical and neurological curricula. Such specimens were previously produced using the freeze-drying method, but were described as «fragile» and «would not stand up to rough handling* (Romero-Sierra et al., 1983). To our knowledge, the dissection and plastination procedure of this kind of specimen never was the subject of a full-length publication (Grondin and Olry, 1996a, 1996b). We describe in this paper the dissection and plastination procedures to obtain a specimen of the human cerebral dura mater with the base of the skull.

Materials and Methods

Removal and fixation of the specimen

An unfixed body, free of any obvious pathological or surgical history (fracture of the skull, meningioma, extradural or subdural hemorrhage) was chosen for this project. Its head was removed through the intervertebral disc between the sixth and seventh cervical vertebrae.

A solution of 10% formalin was injected via both common carotid arteries, and the specimen was immerged in the same solution at 4°C for 24 hours. The specimen was then kept in the solution during its dissection which lasted about three weeks.

Dissection of the specimen

Soft tissues of the scalp (skin, subcutaneous fibro-adipose tissue, epicranial musculature and pericranium) were removed, and a hole (2x2 cm) was pierced in the left parietal bone about 2 cm inferior to the sagittal suture with a Lipshaw autopsy saw (Shandon Lipshaw, Pittsburg, USA). Care was taken to avoid perforation of the underlying cerebral dura mater during this procedure. After removal of the

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piece of bone, a blunt probe was introduced through the cranial aperture to carefully release the dura mater from the inner aspect of the skull. The cranial vault could then be cut piece by piece, in order to make the gradual detachment of the dura mater more easy. The cranial vault was removed down to a line passing inferior to the groove for transverse sinus of occipital bone, above the external acoustic meatus and zygomatic arch, at mid-level of the frontal process of zygomatic bone, and about 1 cm superior to the nasofrontal suture. The base of skull was also dissected, and cervical vertebrae were carefully removed so that the spinal dura mater became visible.

A hole (5x5 cm) was cut in the convexity of the left half of the cerebral dura mater, and the whole brain (prosencephalon, brain stem and cerebellum) could then be pulled out in small pieces through this aperture.

All soft tissues of the face, including eye balls and accessory visual apparatus, were also removed, but the dural sheath of the optic nerve was minutely dissected and preserved.

Plastination of the specimen

The specimen was then dehydrated and impregnated according to the standard S10 procedure (von Hagens, 1985). After impregnation, the whole dural cavity was filled with absorbent paper in order to restore the normal shape of the cerebral dura mater and its septa, and the specimen was fast cured (Weiglein and Henry, 1993).

After complete curing, the opening on the left side was enlarged to permit a full view of the falx cerebri with its inner free margin, as well as the tentorium cerebelli with its tentorial incisure.

Results

The convexity of the cerebral dura mater (figures 1-2) shows arterial ramifications (middle meningeal artery) and the location of the superior sagittal and transverse sinuses. The sheath of the optic nerve appears through the optic canal of the orbital cavity (figure 3).

The aperture of the left side of the dura mater gives a full view of the intradural cavity and its partitioning (figures 4-5). The anterior part of the falx cerebri is attached to the crista galli of the ethmoid bone and is perforated by numerous apertures, as usual (Williams et al., 1989). Many fibrous tracts can be observed at the junction of the falx cerebri with the convexity of the dura mater (Renard et al., 1967). The straight sinus is visible along the attachment of the posterior part of the falx to the tentorium cerebelli. The free border of the tentorium cerebelli and the dorsum sellae of the sphenoid bone delimit the tentorial incisure, and the anterior attachments of the tentorium cerebelli can be followed to the anterior clinoid processes.

Discussion

The aim of this study was to provide students with a plastinated specimen of the cerebral dura mater showing all its morphological and topographical features. The base of skull and parts of bones of the face were preserved, so that topographical relationships between the meninges and its osseous envelope could be better understood.

Unlike the specimen of the same kind produced by using the freeze-drying method (Romero-Sierra et al., 1983), our plastinated specimen can be handled without particular caution. Moreover, the consistency of the cerebral dura mater is comparable with those of fresh, i.e. non plastinated specimens.

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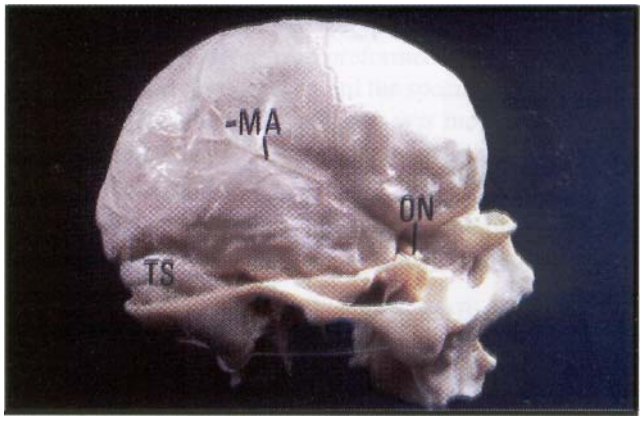

Figure 1. Lateral aspect of the specimen (Norma lateralis). MA - ramifications of the middle cerebral artery, ON - sheath of the optic nerve, TS - transverse sinus.

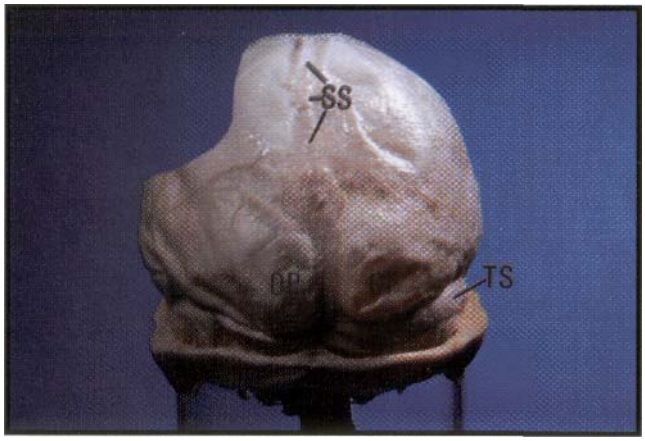

Figure 2. Posterior aspect of the specimen (Norma occipitalis). OP - occipital poles, SS - superior sagittal sinus, TS - right transverse sinus.

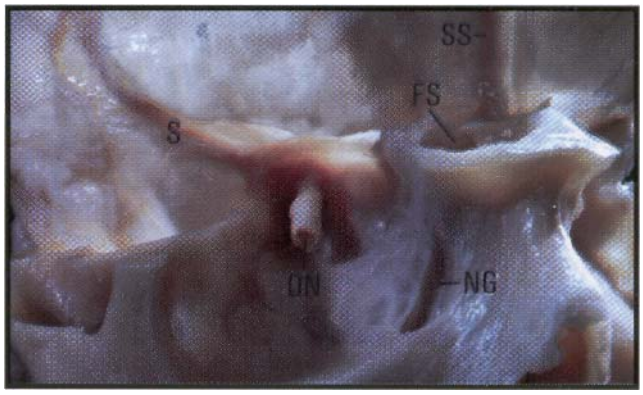

Figure 3. Close view of the orbital region. FS - frontal sinus, NG - nasolacrymal groove, ON - sheath of the optic nerve, S - lesser wing of sphenoid bone, SS - superior sagital sinus.

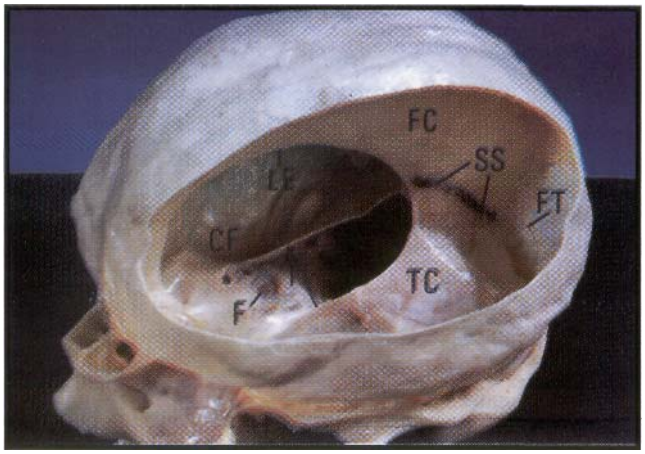

Figure 4. Anterolateral view of the specimen. CF - middle cranial fossa, F - hypophysial fossa, FC - falx cerebri, FT - fibrous dural tract, LE - lower edge of the falx cerebri, SS - straight sinus, TC - tentorium cerebelli, TI - tentorial incisure.

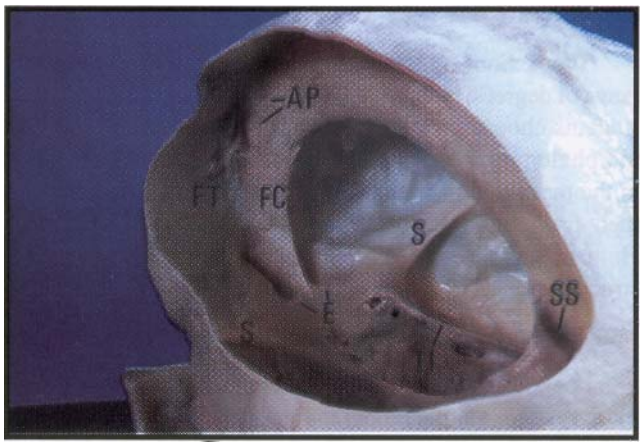

Figure 5. Posterolateral view of the specimen. AP - apertures of the anterior part of the falx cerebri, E - cribriform plate of the ethmoid bone, FC - anterior part of the falx cerebri fixed to the crista galli, FT - fibrous dural tract, S - lesser wings of the sphenoid bone, SS - straight sinus, TI - tentorial incisure.

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Student Participation in Plastination as a Learning Exercise in a Science Degree Embryology Unit.

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Key Words: *Plastination, Embryology, Multimedia, Piglet*

Abstract

Students enrolled in their third year of a Bachelor of Science course at Curtin University used plastination techniques to preserve their dissected specimens as part of the practical component of the embryology module of the Human Structure and Development unit. Students attended an information session on the methodology of plastination. To assess age, foetal pig specimens were measured and weighed. Students then chose developmental features they wished to portray.

Specimens were dissected by the students, dehydrated and plastinated. Progress was monitored by the students with respect to dehydration, shrinkage and colour retention. After 8 weeks the plastinated specimens were examined and their component parts identified. Specimens were photographed with a digital camera and the resulting images imported into a HyperCard stack representing the work of the class. Images were labeled and linked to information about their age and sectioning. The plastinated specimens were retained for future student use.

Participation in the plastination gave the students responsibility for producing their specimens. Students learned specimen preparation combined with image digitisation and multimedia presentation of material. Student evaluation of the plastination component of this unit and examples of their work are presented.

Introduction

The School of Biomedical Sciences offers students a range of degrees, including the BSc in Human Biology. These students choose their majors from three discipline streams; morphology, physiology and molecular genetics. Students in the morphology stream may select four modules to build their final third-year unit. One of these modules is called Human Structure and Development 331 and explores the structural changes which occur during embryological development.

Foetal pig specimens provide an inexpensive and easily-accessible animal model to study developmental changes and correlate with human development. Previously foetal pig specimens were used but the students had difficulty in relating their dissections to the lecture material in a once-off wet laboratory class. Therefore it was decided for the 1995 session to use plastination for preservation and to enhance the learning experience.

Educational rationale

Learning is a collection of activities whereby knowledge is constructed in the mind of the learners from resources presented to them. It is documented that students learn more effectively if engaged in some activity which provides an opportunity to practice the theoretical material from lectures and textbooks (Beard and Senior, 1980; Entwistle, 1981; Laurillard, 1981). Practical classes allow the students to manipulate material in three dimensions and to consolidate ideas which have been generated from reading or listening.

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The use of fresh material is made less useful because it has a limited shelf-life. Preserving with formalin solution has the usual limitations associated with noxious fumes, and requires specific dissection-room facilities. The plastination process allows students to dissect the fresh specimens to show features which they wish to study then preserve them for later use. This reinforces their own understanding and illustrates concepts when working with other students in a collaborative learning tutorial. The plastinated specimens can be used in ordinary classrooms to expand the learning experience of practical work beyond the practical sessions.

In our example, students are actively involved in the selection, preparation and presentation of the specimens rather than merely passively viewing specimens prepared by someone else. Students select their own area of interest to study and are motivated by identifying various components displayed, and understand their functional relationship with surrounding structures.

Materials and Methods

Students attended an information session on the methodology of plastination which was designed to relate to their experience and knowledge of histological techniques. Foetal pig specimens of various stages of development were obtained from a local abattoir. Students examined the specimens, measured and weighed them to determine their various ages. Subsequently they decided which aspects of development they wished to portray in their specimen. Students consulted with the lecturer and the technical expert to reach a decision. Some students opted for equivalent sections of specimens at different stages of development while others chose to section and prosect one specimen to trace detailed structures at a particular age.

Dissection and sectioning was carried out on the fresh specimens while some were immediately frozen to facilitate sectioning. Smaller specimens were sectioned at room temperature using a brain knife and the frozen specimens were sectioned with a band saw. Sectioning was carried out or supervised by technical staff but at all other times students were directly involved in the preparation of their specimens. Specimens were then plastinated using the S10 technique (von Hagens, 1985).

Fixation and dehydration

To accelerate the process the specimens were freeze-fixed (von Hagens, 1985). This ensured that the specimens would be completed within one semester. As an additional advantage, freeze fixation preserves colour better than the traditional fixation and dehydration method. Specimens were submerged in the first acetone bath containing 5% formalin (stabilised with 10% methanol) for two weeks. They were then dehydrated by freeze-substitution in 100% acetone. Both fixation and dehydration were preformed at -25°C. Dehydration continued for 4 weeks until the specimens had a water content of less than 1%. Progress was monitored by the students on a weekly basis with respect to dehydration, shrinkage and colour retention.

Forced Impregnation

Specimens were immersed in polymer (Biodur S10+S3) which was placed inside a vacuum tank in a freezer (-25°C). The specimens were left overnight to equilibrate with the polymer. A vacuum was applied to the impregnation bath and pressure was gradually decreased to 10mm Hg over a three weeks period.

Curing

After impregnation the specimens were drained of excess polymer and then cured with Biodur S6. Due to time constraint, the fast-cure method was adopted as the preferred curing method. The specimens were placed in a sealed chamber with the volatile curing solution (S6). After three days the specimens were dry to touch, allowing the students to handle their specimens quickly after impregnation. The specimens were then stored in a sealed container along with desiccant for three months to allow complete curing.

After 8 weeks from the commencement of the project the plastinated specimens were examined and their component parts identified. The specimens were photographed with a digital camera and the resulting images imported into a hypercard stack called Piglet 95, which represented the work of the class. Students labeled the images and linked this to information about the age of the piglet specimen and to the plane of sectioning.

Results

After the plastination process was completed, the technical success of the specimens was evaluated. A total of 31 pieces were deemed useful for the project (figure 1), representing 82% of the total prepared prosected material. Specimens were considered a failure if they were either incompletely impregnated or fragmented from their original specimen.

Good colour differentiation was exhibited by all specimens. Thoracic and abdominal viscera in particular showed extremely good colour differentiation. In some cases the adipose tissue within the abdominal cavity even retained it's yellow colour. Nervous tissue however was less successful. Shrinkage was quite marked and in many cases the brain,

especially in the smaller specimens lacked the detail expected.

Evaluation of outcomes

The plastination process and subsequent HyperCard stack contributed to 20% of the semester mark. Each student was assessed with regard to their planning and execution of specimen preparation rather than the success of the subsequent plastination. This was the first time plastination of piglets had been attempted in this unit, therefore little was known of the likely success of such preparations. Much of the technical work was supervised or carried out by staff, and there were no guidelines given to students as to the most suitable specimens to plastinate.

In informal focus groups during and at the end of the semester, students spoke of the plastination procedures with enthusiasm. While some of this could have been due to the novelty of doing something which had not been tried before, the combination of practical experience and theory was supported with the idea that the students would have "something to take away with them" at the end of the semester. Negative comments related to the time lag between the prosection of the piglets and the final curing of the plastinated specimens and the time constraints of the S10 procedure.

A sample of students (n=4) which represented 40% of the class were interviewed after the semester was over, and asked to reply to a questionnaire (Table 1). Unfortunately the class, having completed their degrees, had dispersed after their final examination and our sample was restricted. Students replied favourably to the use of plastination within the unit. They found plastination "useful in helping them relate embryological structures in three dimensions and relating them to the changes which occur during foetal development". The students also wanted to be "more involved in the actual technical process giving them more responsibility of the actual plastination of their own specimen".

Peer review assessment was conducted with the assistance of staff in the School of Biomedical Sciences and in the Veterinary School at Massey University in New Zealand, where plastinated sheep brains are used in teaching. Informal focus group sessions were used to share experiences and exchange ideas, but no report on this process has yet been published.

Future Directions

Due to the success of this trial, plastination will be retained in the unit Human Structure and Development 331 at Curtin University. However, as a result of the evaluations conducted and of the trial of alternative plastination techniques, some changes will be made to the timing and certain dissections will be suggested to ensure greater success of the plastination portion of the project.

The S10 process in preserving student specimens certainly proved to be useful and successful. However, due to the length of the process and the time constraint within which we worked, it was felt that if this were to be attempted again the students would have to engage in their selection and dissection of specimens much earlier in the course or alternatively a shorter plastination process be used.

An alternative process, the E12 technique (von Hagens, 1985; Weber and Henry, 1993), has been tried, and has been very successful in showing great detail of foetal structures. The use of this method will have many advantages over the S10. Although technically more challenging than S10, it could allow a shorter processing time. This reduces the timelag between sectioning and end product, and thus will allow students to work more extensively with their plastinated specimen. Of all the prosections tested, more students opted for sectioning their specimens, and these sections proved to be very successful, E12 works extremely well for sectioned specimens. E12 plastination sections are thinner which allows greater topographical investigation of developing viscera within the foetal pig. Hollow organs are preserved in E12 but are often lost using S10.

With more time for development of ideas using the specimens in class, plastination in the future will further enhance the learning experience. It will also allow for increased self-directed learning as these specimens can easily be used in the library or at home. In the future, students will be more directly involved during the technical procedures of plastinating their specimens. This will increase their perceptions as stakeholders in their learning.

Conclusion

Plastination of foetal piglet specimens allows students to relate to histological and basic morphological techniques: e.g. prosection, resin embedding and progressive dehydration. It reinforces concepts of the scientific method and enhances the learning of a difficult section in morphology - embryological development. The generation of a HyperCard stack of images, to illustrate the students' input into a tangible representation of their learning, was an important adjunct to the plastination process.

The HyperCard stack, Piglet 95, can be viewed at the Human Biology Multimedia website: http://www.curtin.edu.au/curtin/dept/biomed/teach/hubiol/hb.html

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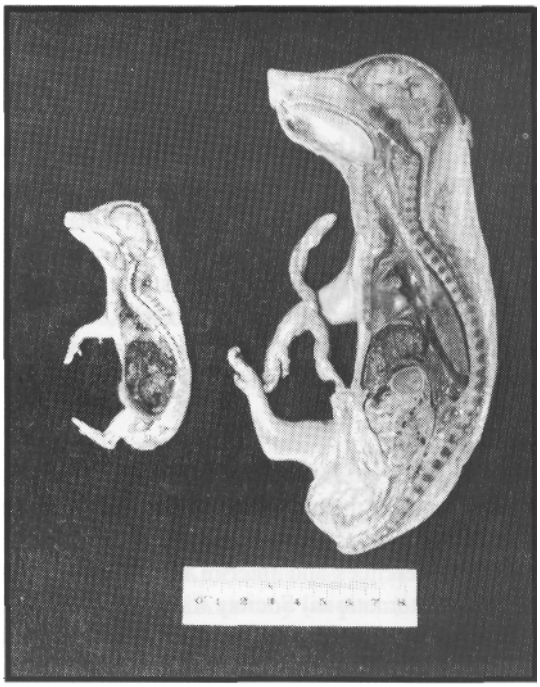

Figure 1. Plastinated 20 (left) and 60 (right) day foetal pig specimens. Midsagittal sections

Table 1.
Questionnaire Piglet 95

Did the plastination process help you:

i) in understanding specimen preparation techniques?	No 1	yes 5
ii) in understanding embryology?	No 1	yes 5
iii) in gaining an appreciation of the scientific process?	No 1	yes 5
iv) in motivating you to learn?	No 1	yes 5

What was the most positive thing about using plastination in the HS&D unit?

What was the most negative thing about using plastination in the HS&D unit?

THESIS REVIEW

La Plastination: de la Théorie à la Mise en Application

Author: P. Poncot, Faculty of Pharmaceutical and Biological Sciences, The University of Nancy 1, France, 1993.

Philippe Poncot was the first student to choose plastination as the subject of a doctoral thesis. He submitted in July 1993 a thesis entitled "La Plastination: de la Théorie à la mise en Application" (Doctor of Pharmacy, University of Nancy).

The aims of the study are:

1. To summarize the history of plastination, of the International Society for Plastination and its scientific events (International Conferences and Interim Meetings), and of the Journal of the International Society for Plastination.
2. To describe the general principles of plastination and its four steps.
3. To draw up the list of equipment required for starting a new plastination laboratory.
4. To give a detailed description of the S10 technique.
5. To debate the place of plastination in French universities.

The first chapter (pp. 1-2) includes the aims of the thesis.

The second chapter (pp. 3-12) summarizes the history of plastination, and gives an account of the plastinators network all around the world: International Society for Plastination and its Journal, previous conferences, and addresses of experienced plastinators.

The third chapter (pp. 13-55) describes the general principles of plastination (fixation, dehydration, forced impregnation and curing), and its current potential in anatomy, pathology, anthropology, museography, mycology and forensic science.

The fourth chapter (pp. 56-67) centers on the S10 procedure, and describes step by step its technical aspects.

The fifth chapter (pp. 68-72) gives a brief summary of the other plastination procedures (E12, P35, PEM).

The conclusion (pp.73-75) analyzes the cost of plastination and its feasability in French universities.

The bibliography includes 23 references.

Though not based on personal experimental research, this thesis has to be regarded as one of the first steps in the introduction of literature on plastination in France. In 1993, the University of Nancy was about to start the first French plastination laboratory, and this thesis had the merit of being a kind of handbook intended for beginners in plastination. More than its content, the date of publication and the country in which the thesis was submitted explain that Mr. Poncot's thesis has to be considered as a landmark in the history of plastination in France.

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Current Plastination Index - Updating

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Aims

The Journal of the International Society for Plastination (ISSN 1090-2171) is an international forum for the diffusion of the plastination technique among scientists interested in preservation of biological specimens for teaching and research. The Journal permits communication of every new application or development of the plastination technique, as well as any other innovating complementary preservation technique, applicable to animal or plant specimens.

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Each paper needs an abstract of up to 20 lines, summarizing the essential new information communicated. Abbreviations and citations should be avoided in the abstract.

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Tables and illustrations (both numbered in Arabic numerals) must be cited in the text and should be prepared on separate sheets. Tables require a heading and illustrations a legend, also prepared on a separate sheet. They should be one column (8.4 cm) or two columns (18 cm) width. On the back of each illustration, indicate its number, the author's name, and "top". For the reproduction of illustrations, only good drawings and original photographs can be accepted.

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References to published works, abstracts, personnal communication and books should be limited to what is relevant and necessary. Citations in the text should be given in parentheses; e.g., (Bickley et al., 1981; von Hagens, 1985; Henry and Hayes, 1989) except when the author's name is part of a sentence; e.g., "von Hagens (1985) reported that..." When references are made to more than one paper by the same author, published in the same year, designate them as a. b. c. etc.

Bibliography

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Examples are as follows:

Bickley HC, von Hagens G, Townsend FM: An improved method for preserving of teaching specimens. Arch Pathol Lab Med 105: 674-676, 1981.

Henry R, Haynes C: An Atlas and Guide to the Dissection of the Pony, 2nd Ed. Edina, MN: Alpha Editions, pp 25-88, 1989.

von Hagens G: Heidelberg Plastination Folder: Collection of all technical leaflets for plastination. Anatomische Institut 1, Universität Heidelberg, Heidelberg, Germany, 1985.

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